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THESIS

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by

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ABSTRACT

The Ships Supply Support Study developed a fleet supply support simulator in which supply support dollar outlays may be related to fleet capability. A critical assumption made in the development of the simulator states that the availability of an item at a given echelon is independent of its availability at other echelons. A study is devoted to the exploration of this assumption. A computer model of a single item multi-echelon supply support system is constructed. A day by day history of the status of each entity in the system is obtained along with an in and out of stock profile for the item by calendar time at each echelon. Marginal availabilities and conditional availabilities are compared, and other measures of the degree of dependence of echelon availabilities are presented. Finally, the computer model is extended to consider a multi-item supply system and similar tests are made.

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TABLE OF SYMBOLS AND ABBREVIATIONS

a_i - Conditional Availability at Echelon i

A_i - Marginal Availability at Echelon i

A_o - Operational Availability

AFS - Combat Stores Ship

AIMS - Afloat Inventory Management Simulator

COG - Material Cognizance Class

COSAL - Consolidated Shipboard Allowance List

DSA - Defense Supply Agency

FILL - Fleet Issue Load List

ICP - Inventory Control Point

MADT - Mean Administrative Delay Time

MLSF - Mobile Logistics Support Force

MLDT - Mean Logistic Delay Time

MSRT - Mean Supply Response Time

MTBF - Mean Time Between Failure

MTTR - Mean Time to Repair

Q - Reorder Quantity

R - Reorder Level

S^4 - Ships Supply Support Study

S - Chi-squared Test Statistic

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I. INTRODUCTION

In August of 1971 a study of supply support to the ships of the United States Naval fleet was directed by the Chief of Naval Operations [Ref. 1]. This was to be an in-house study denoted the Ships Supply Support Study or more commonly by the acronym S^4. The purpose of S^4, as stated in the study directive, is to "define, develop, and propose an automated method by which supply support dollar outlays may be related to fleet capability." This goal was to be achieved by developing and studying a computer simulation model, the Supply Support Simulator - Mark I version and later expanding the simulator by developing a more complex model called Mark II. This simulator was designed to provide answers to questions such as the following:

A. What is the relation of operational availability and requisition response time; i.e., what is the effect on operational availability if requisition response time is reduced or increased drastically?

B. What would happen to requisition response time if the Consolidated Shipboard Allowance List (COSAL) were increased or decreased by a specified percentage?

C. What would happen if the Mobile Logistic Support Force (MLSF) were relieved of all end-use requisition functions?

D. What would be the effect if all Defense Supply Agency (DSA) managed items were requisitioned directly from the DSA Supply Center?

E. What would happen if budgets were increased or decreased at an Inventory Control Point (ICP)?

F. Similarly, what if the staff at an ICP were increased or decreased by a specified number of personnel?

To accomplish this program, a computer model of a portion of the Naval Supply System was constructed. This model consisted of five inventory simulators and one synthesizer. The output of the model consists of estimates of the average requisition response time by Material Cognizance Class (COG). This output can then be manipulated and utilized to answer questions such as those posed earlier.

One of the assumptions made by the Ships Supply Support Study group in arriving at their results is that the availability of an item at a given echelon is independent of its availability at other echelons [Ref. 2]. The purpose of this paper is to investigate the validity of that assumption. In order to do so a computer simulation of a simplified supply support system was developed to give information as to the degree of dependence and to calculate measures which allow for statistical tests to be performed.

II. SHIPS SUPPLY SUPPORT STUDY BACKGROUND

Before undertaking the testing of the validity of the assumption of independence among echelons of supply, a background study of the S^4 project was made. To accomplish the S^4 program, a computer model of a portion of the Naval Supply System was constructed. To facilitate the building of simple, first-cut model, the Sixth Fleet in the Mediterranean was selected as the fleet support supply system to be modeled. This fleet was selected because it was comparatively simple (compared to other fleet support systems) and the data base necessary was readily available. Specifically, a force of selected ships was utilized to represent the fleet and the forces supporting it. Later, of course, only the input parameters need be changed to adapt the model to any Naval supply support operation.

Basically, the Sixth Fleet supply support system is the same as that of the other fleets. A requisition originating at a ship is either satisfied at the ship itself or passed to the next higher support level. Screening of "sister" ships and facilities occurs whenever the requisition is for an emergency, or CASREP item. This higher support level is either the Mobile Logistics Support Force (MLSF) if the part is on the MLSF's load list (FILL), or to the Naval Supply Center (ar Norfolk in the case of the Sixth Fleet), if the part is a non-fill item. From this level the requisition can flow either to a Naval ICP, Defense Supply Center or the General Services Administration warehouse depending on the nature of the item. The alternative actions available at various levels is indicated in the flow chart of Figure 1.

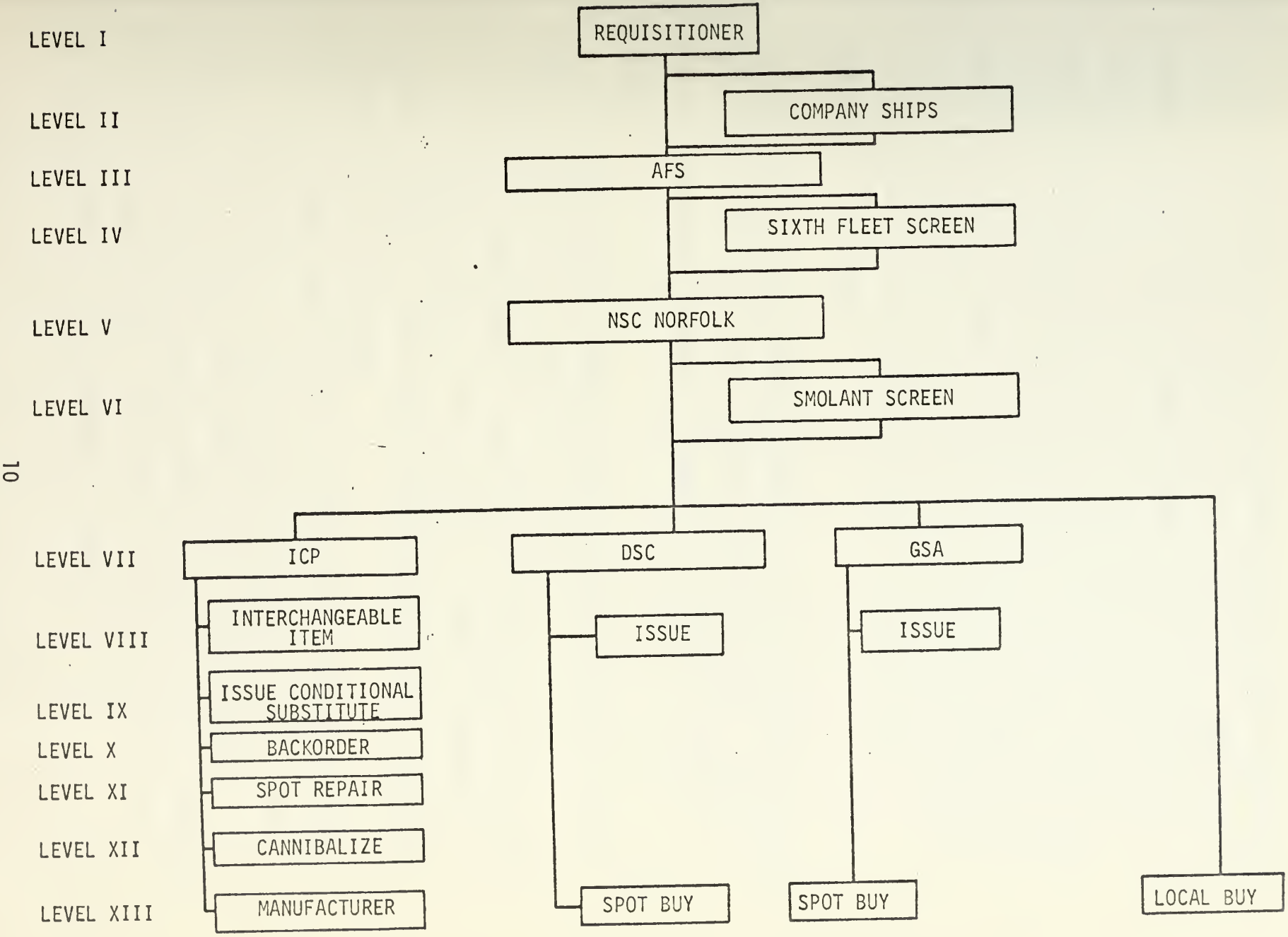
LEVEL I
REQUISITIONER
LEVEL II
COMPANY SHIPS
LEVEL III
AFS
LEVEL IV
SIXTH FLEET SCREEN
LEVEL V
NSC NORFOLK
LEVEL VI
SMOLANT SCREEN
LEVEL VII
ICP
DSC
GSA
LEVEL VIII
INTERCHANGEABLE ITEM
ISSUE
ISSUE
LEVEL IX
ISSUE CONDITIONAL SUBSTITUTE
LEVEL X
BACKORDER
LEVEL XI
SPOT REPAIR
LEVEL XII
CANNIBALIZE
LEVEL XIII
MANUFACTURER
SPOT BUY
SPOT BUY
LOCAL BUY

FIGURE 1

The first or Mark I version of the Supply System Support Study consisted of five inventory simulators and one synthesizer. These were designed to explore the relationship between supply effectiveness and the funds available. That is, Mark I investigates at each level the ratio of the number of requisitions filled to the number of requisitions received as a function of the funds available at that level. This, plus throughput times and supply availability is utilized to produce an estimate of the requisition response time. The later or Mark II version of S^4 will refine and extend the Mark I model. In general, Mark I operation is as follows:

A. This ship or fleet simulator, known as the Afloat Inventory Management Simulator (AIMS) places actual demands on the ship's COSAL. Actions to satisfy the demand are taken and receipt of the item requisitioned is noted.

B. The Mobile Logistics Support Force Simulator is identical to AIMS. Only a slight change in input data is required.

C. The Stock Point Simulator in Mark I is for single items only and not a multi-warehouse simulator. This simulator is used to forecast the probability that the stock point (at Norfolk) can satisfy a requisition submitted by a requisitioner.

D. The Inventory Control Point is modeled by two simulators to account for minor variations in requisition processing between the Electronic Supply Office and Ships Parts Control Center. Basically, however, the simulators are identical and are constructed similarly to the stockpoint simulator described above. Input data is different from that of the stockpoint simulator but the output is virtually the same.

E. The synthesizer receives the output from each of the other simulators as its input and estimates the mean supply response time by COG and the inventory and work load associated with each response time.

III. MEAN SUPPLY RESPONSE TIME

In order to evaluate the various cost tradeoffs that can be analyzed in a complex multi-echelon supply system such as that of the Navy, a measure of effectiveness must be chosen. In the Ships Supply Support Study operational availability is used for this purpose. The operational availability of a component is defined as the ratio of the mean time between failure (MTBF) to the sum of the mean time between failure, the mean time to repair (MTTR) and the mean logistic delay time (MLDT):

$$A_o = \frac{MTBF}{MTBF + MTTR + MLDT}$$

Mean logistic delay time is further partitioned into mean administrative delay time (MADT) and mean supply response time, (MSRT), where the latter is defined to be the average amount of time required to get the needed unit into the hands of a mechanic aboard the requisitioning ship. Absorbing the administrative delay time into the time to repair, operational availability is written as:

$$A_o = \frac{MTBF}{MTBF + MTTR + MSRT}$$

Studies have indicated that MSRT appears to average about 30 to 40 times the combined value of mean administrative delay time and mean time to repair [Ref. 3]. Thus, MSRT is generally the driving factor in the equation for operational availability. It becomes important to know how improvements can be made in MSRT.

Mean supply response time is itself a function of the structure and behavior of the supply system. Suppose a system has n echelons with the lowest being the ship store room and the n^{th} echelon being the manufacturer of the part. Whenever a unit fails, a replacement is supplied from the ship's storeroom if the part is available; otherwise, a requisition is sent forward through the successive echelons until it is either supplied or manufactured. The mean supply response time is then the sum of the response times of each echelon weighted by the fraction of total requirements it satisfies. Mathematically,

$$MSRT = a_1 t_1 + \sum_{j=2}^{n} a_j t_j \prod_{i=1}^{j-1} (1-a_i)$$

where a_j = the probability that the j^{th} echelon activity is able to satisfy an end-use requisition given that it cannot be satisfied by a lower echelon.

t_j = the time from the mechanic's need for a unit of material until his receipt from the j^{th} echelon activity.

Recognize that the inventory at each echelon, except the first and last echelons, serves two purposes: (1) it supplies items to the end user which are not carried by any lower echelon or not available at any lower echelon, and (2) it resupplies each lower echelon directly or indirectly to maintain the availability of that echelon. In the expression for MSRT note that the weight given to the time t_j is,

$$a_j \prod_{i=1}^{j-1} (1-a_i).$$

This represents that fraction of material needed for repair which is available at the j^{th} echelon and not available at any of the lower echelons. Thus, a_j, the conditional availability, refers to the ability of echelon j to supply those parts which lower echelons stocked, but which were temporarily out of stock and those parts which lower echelons did not stock. This availability figure is generally lower than the figure which represents the ability of an echelon to replenish or resupply stocks carried at lower echelons and to satisfy end-use requisitions. Thus, theoretically, it is only at the ship level and the manufacturer's level that the availability to satisfy immediate requirements is equal to the conventionally measured gross availability.

In the Ships Supply Support Study it was assumed that the availability of an item at a given echelon is independent of its availability at other echelons [Ref. 1]. Define the marginal availability, A_i, for echelon i as follows:

A_i = Probability that echelon i will be able to satisfy a requisition.

The independence assumption made above, in effect, says that the marginal availabilities A_i can be used in place of the conditional availabilities a_i. Indeed, the use of A_i is certainly more convenient, for it is estimated simply by dividing the number of requisitions filled by the total number of requisitions. However, it is not clear what is the impact of the assumption.

The stock profile for a given item at echelon i can be viewed as an alternating renewal process:

$$Z_i(t) = \begin{cases} 1 \text{ if the item is in stock at echelon } i \text{ at time } t \\ \\ 0 \text{ otherwise.} \end{cases}$$

Typically, it would be expected that whenever a given echelon is out of an item the lead time is short if the next higher echelon is in stock, but it is long if the resupply must be made from an activity several echelons removed. Thus, long intervals of time in which several echelons are each out of stock would not seem unlikely. When this happens, the availability suffers an adverse effect.

IV. METHOD OF ATTACK

The purpose of this study is to test the hypothesis that the set of alternating renewal processes describing the stock profiles of each echelon is a set of independent processes, and to quantify the importance of the dependence if the hypothesis is rejected. In order to test the hypothesis, the stock profile for each item must be examined by calendar time so that all echelons can be placed on a common time scale. This necessitates following each requisition, both for end use and resupply, throughout the supply system until it is satisfied.

Nowhere in the Navy is data available which traces the movement of a particular requisition through successive echelons until material is supplied. This excludes a data oriented study of independence based on available data. A second approach would be to study the assumption by modeling the multi-echelon supply system as a system of alternating renewal processes. Such a model would depend on a knowledge of the inventory policy of each echelon, the distribution of demand from each activity, and the interactions between the echelons. Unfortunately, attempts to model even very simple multi-echelon supply systems analytically have proven to be unsuccessful. This is particulary true if it is desirable to be able to follow requisitions throughout the system. The computational implications to obtaining an analytic solution seem infeasible.

Because of the difficulties associated with the two most direct approaches a decision was made to study the problem by simulating a hypothetical multi-echelon supply system. A set of representative items

was selected for study. The number of echelons considered in the simulation model was reduced to four for simplicity. The hypothetical supply system has the following activities:

SHIPS	ECHELON 1
AFS	ECHELON 2
ICP	ECHELON 3
MAFG	ECHELON 4

Because of the reduction in the size of the inventory system, the magnitude of actual supply response times or other quantitative measures have questionable interpretation; however, it was felt that an answer to the question about independence could be obtained by studying the simpler supply system.

Assumptions about stocking policies, resupply policies, and resupply times follow as closely as possible those which have been incorporated into the Ships Supply Support Study. These are discussed in the next section. Demands aboard the ships are generated randomly in accordance with instructions in S^4. All effort was made to make the simulator as realistic as possible. The demand parameters, load lists, reorder quantities, reorder levels and throughput times are all inputs which can be easily modified to accomodate changes.

The simulator was designed to give a day by day history of the status of each activity. It also provides the stock profile for a given item by calendar time at each echelon. These place all echelons on a common time scale and show the relations between the item availability at a

given echelon and its availability at the other echelons. Additionally, conditional availabilities and marginal availabilities are calculated at each echelon, and comparisons are made. From these outputs statistical tests of the independence were performed.

To illustrate the impact of any dependence, mean supply response times were calculated two ways. The first method used the appropriate conditional availabilities a_i, and the second employed the marginal availabilities, A_i.

Lastly, the simulation model was extended to consider a multi-item system so that weapon system availability could be examined.

V. SIMULATION MODELS

A. SINGLE ITEM MODEL

1. General

The single item model simulates a fleet supply support system consisting of four echelons. These echelons are:

a. The fleet composed of three ships.

b. The support ship (AFS).

c. The Continental United States based supply point (ICP).

d. Manufacturer.

The modeling of each echelon is discussed in the material which follows.

2. First Echelon (The Fleet)

Random demands for a single item are generated according to a "Stuttering Poisson" distribution. These demands and the dates they occur are stored to be called in sequence as the time clock advances. The spare stock carried aboard a ship to support the given item is determined in accordance with COSAL regulations; that is, the spare stock is that quantity which provides 90% protection for a 30 day period of time. If, on the date the demand occurs, the ship's on-hand stock is adequate to fill the amount demanded, then the requisition is filled immediately and the on-hand stock level decreased by the appropriate amount. A routine requisition is forwarded the same day to the support ship (AFS) for replenishment which will occur whenever the AFS next visits the ship (if stock is on hand at the AFS). This replenishment occurs randomly in zero to thirty days depending on the physical location of the AFS when the requisition is received.

If the requisition can not be filled by the shipboard COSAL, then it becomes a priority requisition and it is forwarded to the AFS or ICP. The decision as to which level the requisition is to be forwarded is determined by the on-hand stock at the AFS. If the AFS stock is adequate to fill the demand the requisition is sent there; if not, the requisition is sent to the ICP. Priority resupply of the ship occurs in a maximum of eight days from stock on the AFS or in twenty-one days from the ICP. Once again the number of days from the AFS to the ship is dependent upon where the AFS is located relative to the position of the ship when the priority requisition was received by the AFS.

3. Second Echelon (The AFS)

A requisition is received from a ship only if the AFS stock is adequate to fill the demand. The spare stock depth for the AFS is calculated just as the spare stock for each ship was determined. For routine requisitions, the item is tagged as in-transit and held until the AFS and the ship rendezvous. As explained earlier, this occurs randomly in zero to thirty days depending on the location of the AFS.

When a priority requisition is received by the AFS, a search is made first of on-hand stock and then of in-transit items to fill the order. If an item which is in transit to a ship is utilized to fill a priority requisition, the AFS forwards a routine requisition to the ICP for routine delivery of an item directly to the ship.

Replenishment stock for the AFS is ordered immediately as the on-hand stock is decreased. The AFS is then resupplied from the ICP at forty-five day intervals (i.e., the AFS returns to port).

4. Third and Fourth Echelon (ICP, Manufacturer)

Routine requisitions received by the ICP are coded as to originator and filled from stock or back-ordered as appropriate. The items ordered are shipped to storage bins at the ship's home port where they await pick-up by the ship or AFS. Priority requisitions are handled similarly except they are sent directly to the ships by an expedited means. (The AFS does not submit priority requisitions to ICP.) Shipment time required twenty-one days from receipt of the requisition at the ICP until receipt of the item at the ship.

The ICP operates on an (R,Q) stockage policy; that is, whenever the on-hand level reaches a level R, a quantity of Q items is ordered from the manufacturer. Delivery from the manufacturer requires six months (180 days). Upon receipt of items from the manufacturer, first the priority back-orders are filled and then the routine back-orders. Any items remaining are placed in stock.

5. Operation of the Models and Output

To operate this model the following input data is required:

a. COSAL level of each ship.

b. COSAL level of the AFS.

c. Demand rate for each ship.

d. Rate for the Stuttering Poisson.

e. R and Q for the ICP.

f. Initial on-hand stock levels for the ICP.

The model simulates a period of three years. All output occurs at the completion of the simulation. A day by day history of the on-hand stocks levels at each ship, the AFS and at the ICP for the entire length

of the simulation (three years) was obtained. This allowed a requisition to be traced from its initiation to the final supply action of filling this requisition and/or any other requisitions generated as a result of its passing from one level to another. In addition, the marginal and conditional availabilities at each supply level were determined.

Marginal availability was estimated as the ratio of the number of requisitions filled to the number of requisitions received at a given level. Similarly, conditional availability at echelon i was estimated by the ratio of the number of requisitions filled at echelon i which could not be filled at any lower echelon to the total number of requisitions received by echelon i which could not be filled at any lower echelon.

Finally, values of the test statistics to be used for the Chi-squared tests of independence of echelon availabilities were calculated.

B. MULTI-ITEM MODEL

In general, the multi-item model is identical to the single item model. Now an entire weapons system consisting of fifty parts is supported by the supply system. This allows calculation of the weapons system availability as it relates to supply support. The differences are:

1. The fleet of three ships has been replaced by one ship with a stockage allowance for fifty items.

2. The AFS is still a single ship but it now stocks fifty items. Each is handled identically in the same manner as in the single item model. However, the AFS arrives at the ship on a regular cycle and transfers all items due-in to the ship at that time.

3. The ICP operates identically as before except fifty items are stocked.

Input data is virtually the same. Output consists of the marginal and the conditional availabilities calculated for each of the fifty parts at each of the three levels. Additionally, the weapons system availability is calculated. This is the ratio of the number of days the weapons system is operational to the total number of days. An operational day occurs whenever there are no priority requisitions outstanding at the shipboard level.

VI. CONCLUSIONS

To demonstrate the validity or non-validity for the assumption being tested in this study, it was necessary to exercise the computer model several times using a variety of input parameters. This was done to insure that resultant output be obtained for a representative spectrum of item characteristics. The results of these computer runs are summarized in Table 2.

As is obvious from the table there is overwhelming evidence that the marginal availabilities exceed the conditional availabilities. This in itself is a strong indication of the fallacy of the assumption tested. To further verify what appears to be true just by observing the results presented in Table 2, a Chi-squared test for independence was conducted.

As an example of this test consider the following contingency table:

	SHIP on-hand ≥ 0	SHIP on-hand < 0	
AFS on-hand ≥ 0	N_{11}	N_{12}	$N_{1\cdot}$
AFS on-hand < 0	N_{21}	N_{22}	$N_{2\cdot}$
	$N_{\cdot 1}$	$N_{\cdot 2}$	N

TABLE 1. Contingency Table

COSAL QUANTITIES			RECORDER DATA		MARGINAL AVAILABILITIES			CONDITIONAL AVAILABILITIES		MEAN SUPPLY RESPONSE TIMES	
SHIP	AFS	ICP	R	Q	SHIP	AFS	ICP	AFS	ICP	A_i	a_i
1	2	9	7	4	0.7391	0.7174	0.7391	0.4167	0.4286	4.93	11.31
1	1	9	7	4	0.8421	0.4474	0.8421	0.0000	0.8333	-----	-----
1	0	9	7	4	0.6042	0.0000	0.5625	0.0000	0.3684	-----	-----
1	2	9	4	3	0.4222	0.4444	0.3111	0.2692	0.0526	26.48	41.90
1	1	9	4	3	0.5897	0.4103	0.3590	0.1875	0.0769	-----	-----
1	0	9	4	3	0.3333	0.0000	0.2917	0.0000	0.1250	-----	-----
1	2	9	6	3	0.5952	0.5714	0.5000	0.3529	0.1818	12.64	23.87
1	1	9	6	3	0.7436	0.4615	0.6410	0.3000	0.2857	8.14	14.88
1	0	9	6	3	0.4583	0.0000	0.3750	0.0000	0.1538	-----	-----
1	2	9	9	4	0.8462	0.8205	0.9487	0.5000	0.3333	2.12	6.71
1	1	9	9	4	0.8919	0.4865	0.9459	0.0000	0.7500	-----	-----
1	0	9	9	4	0.6250	0.0000	0.7500	0.0000	0.7222	-----	-----
0	2	9	7	4	0.0000	0.6250	0.5625	0.6250	0.3889	25.84	30.98
0	1	9	7	4	0.0000	0.1250	0.5000	0.1250	0.4524	-----	-----
0	0	9	7	4	0.0000	0.0000	0.5625	0.0000	0.5625	-----	-----
0	2	9	4	3	0.0000	0.3125	0.2917	0.3125	0.0909	55.41	67.00
0	1	9	4	3	0.0000	0.1875	0.2917	0.1875	0.1795	64.03	71.23
0	0	9	4	3	0.0000	0.0000	0.2917	0.0000	0.2917	-----	-----
0	2	9	6	3	0.0000	0.4792	0.3750	0.4792	0.1200	-----	-----
0	1	9	6	3	0.0000	0.1042	0.4167	0.1042	0.3721	60.92	64.08
0	0	9	6	3	0.0000	0.0000	0.3750	0.0000	0.3750	-----	-----
0	2	9	9	4	0.0000	0.6667	0.7500	0.6667	0.6250	-----	-----
0	1	9	9	4	0.0000	0.1250	0.8125	0.1250	0.7587	-----	-----
0	0	9	9	4	0.0000	0.0000	0.7500	0.0000	0.7500	-----	-----
*1	3	12	15	9	0.4510	0.5490	0.5294	0.4464	0.3548	17.04	24.06
*2	3	12	15	9	0.7400	0.4500	0.6300	0.3462	0.7059	-----	-----
*1	3	12	20	9	0.4851	0.6139	0.9307	0.5192	0.9200	-----	-----
*2	3	12	20	9	0.8198	0.5586	0.8108	0.3000	0.6429	-----	-----
*1	3	12	12	9	0.3627	0.4118	0.4804	0.2769	0.4255	25.54	30.25
*2	3	12	12	9	0.6900	0.5100	0.5400	0.3226	0.3810	-----	-----

*Ship demand rate is 1/30 days. All others are 1/90 days.

TABLE 2. Availabilities and MSRT

Where N_{ij} is the number of days the stated condition holds and

$$N = \sum_{i=1}^{2} \sum_{j=1}^{2} N_{ij}$$

is the total number of days. The contingency table provides a method for investigating suspected relationships. Let

$$X = \begin{cases} 0 \text{ if the ship on-hand stock is less than 0} \\ 1 \text{ otherwise} \end{cases}$$

and

$$Y = \begin{cases} 0 \text{ if the AFS stock on-hand is less than 0} \\ 1 \text{ otherwise} \end{cases}$$

Now define the following joint probabilities and marginal probabilities:

$$P[X = 1, Y = 1] = P_{11}$$
$$P[X = 1, Y = 0] = P_{12}$$
$$P[X = 0, Y = 1] = P_{21}$$
$$P[X = 0, Y = 0] = P_{22}$$

$$P[X = 1] = p_1 \qquad P[X = 0] = p_2$$
$$P[Y = 1] = q_1 \qquad P[Y = 0] = q_2$$

Then the null hypothesis that the AFS and the ship classifications are independent is equivalent to the null hypothesis:

$$H_o: \ P_{ij} = p_i q_j \qquad i = 1,2, \ j = 1,2$$

Using maximum likelihood estimates of these probabilities, $\hat{P}_{ij}$, it can be shown that for large sample sizes the test statistic

$$S = \frac{(N_{11}-N\hat{P}_{11})^2}{N\hat{P}_{11}} + \frac{(N_{12}-N\hat{P}_{12})^2}{N\hat{P}_{12}} + \frac{(N_{21}-N\hat{P}_{21})^2}{N\hat{P}_{21}} + \frac{(N_{22}-N\hat{P}_{22})^2}{N\hat{P}_{22}}$$

is approximately Chi-squared distributed with one degree of freedom. Thus, the test of independence reduces to a comparison of the test statistic S with the value $\chi_\alpha^2(1)$ obtained from Chi-squared tables. If S exceeds $\chi_\alpha^2(1)$ the null hypothesis is rejected.

At the .05 level of significance, the value of $\chi^2(1)$ is 3.843. Denote those runs where either the ship or the AFS fails to stock the given item (COSAL or FILL is zero) or where the item is available 100% of the time at either echelon as "degenerate" cases. Then, as can be observed from Table 3, the value of the test statistic consistently exceeds the value 3.843 for the nondegenerate cases. Furthermore, the test statistics usually exceed 3.843 by a substantial margin. These tests indicate that, for the nondegenerate cases studied, the availability of an item at the first echelon is not independent of the availability of the item at the second echelon. For the degenerate cases it can be easily shown that $P_{ij} = p_i q_j$, that is, the AFS and the ship classification are independent. Similar tests of the independence of the availabilities of the first and third echelons and the second and third echelons all point to the same conclusions. These test statistics are also presented in Table 3. Obviously, these conclusions can only be made for the particular items studied. However, because of the wide range of item characteristics examined and the consistency by which the test statistics exceed the value $\chi_\alpha^2(1)$, there is strong evidence that the item availability at a given echelon depends on the item availability at the other echelons except in degenerate cases.

COSAL QUANTITIES			REORDER DATA		CHI SQUARED STATISTICS		
SHIP	AFS	ICP	R	Q	SHIP/AFS	SHIP/ICP	AFS/ICP
1	2	9	7	4	202.76	62.61	35.43
1	1	9	7	4	197.13	47.84	52.73
1	0	9	7	4	0.00	101.10	0.00
1	2	9	4	3	532.17	534.37	335.92
1	1	9	4	3	72.59	389.39	110.29
1	0	9	4	3	0.00	214.98	0.00
1	2	9	6	3	252.98	157.94	221.00
1	1	9	6	3	151.09	214.39	39.02
1	0	9	6	3	0.00	170.62	0.00
1	2	9	9	4	283.43	2.00	38.60
1	1	9	9	4	236.41	9.79	14.43
1	0	9	9	4	0.00	117.27	0.00
0	2	9	7	4	0.00	0.00	198.57
0	1	9	7	4	0.00	0.00	79.40
0	0	9	7	4	0.00	0.00	0.00
0	2	9	4	3	0.00	0.00	332.69
0	1	9	4	3	0.00	0.00	186.97
0	0	9	4	3	0.00	0.00	0.00
0	2	9	6	3	0.00	0.00	226.33
0	1	9	6	3	0.00	0.00	123.13
0	0	9	6	3	0.00	0.00	0.00
0	2	9	9	4	0.00	0.00	69.68
0	1	9	9	4	0.00	0.00	37.87
0	0	9	9	4	0.00	0.00	0.00
*1	3	12	15	9	88.90	118.73	65.24
*2	3	12	15	9	41.12	89.14	7.95
*1	3	12	20	9	0.38	98.83	13.16
*2	3	12	20	9	154.23	26.26	18.28
*1	3	12	12	9	119.61	10.25	7.58
*2	3	12	12	9	64.15	61.10	7.79

*Ship demand rate is 1/30 days. All others are 1/90 days.

TABLE 3. Chi-Squared Statistics

To examine the impact of the dependence, mean supply response time was calculated for several of the runs using, first, the marginal availabilities in the equation for MSRT and then the conditional availabilities. These calculated values of MSRT are presented in the last two columns of Table 2. The sample values show that the difference can be substantial. In some cases the difference exceeds 100%. In all cases, the MSRT using marginal availabilities underestimates the correctly calculated value. The differences are smallest in the degenerate cases. From these calculations it would appear that the mean supply response times determined by S^4 would underestimate the true mean supply response time.

The day by day comparison of the stock position of each echelon is presented graphically in Table 4. This graph shows that runs occur in which several echelons are all out of stock, thus producing a possible adverse effect on the logistic support of the supply system.

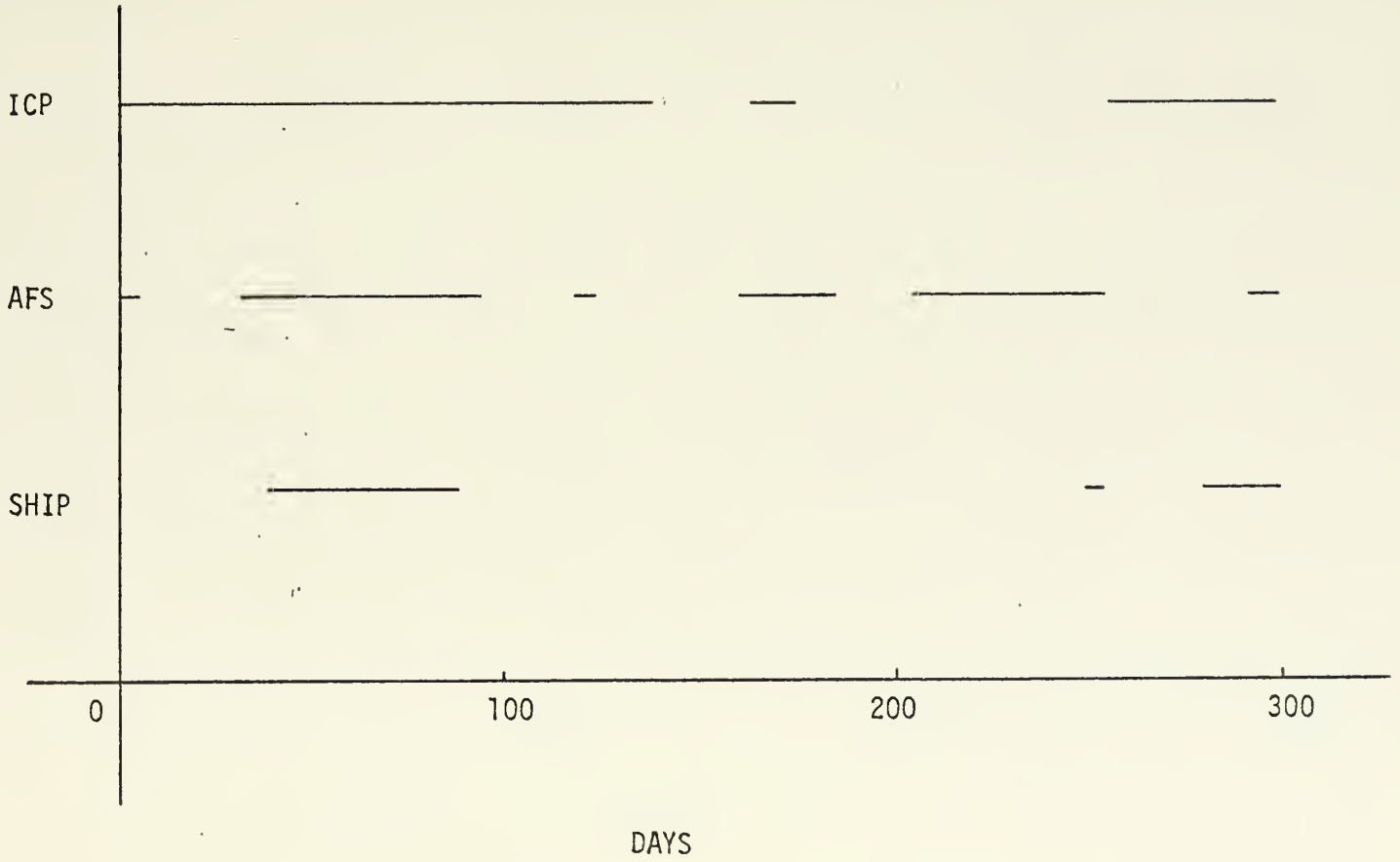

TABLE 4. Stock Profile

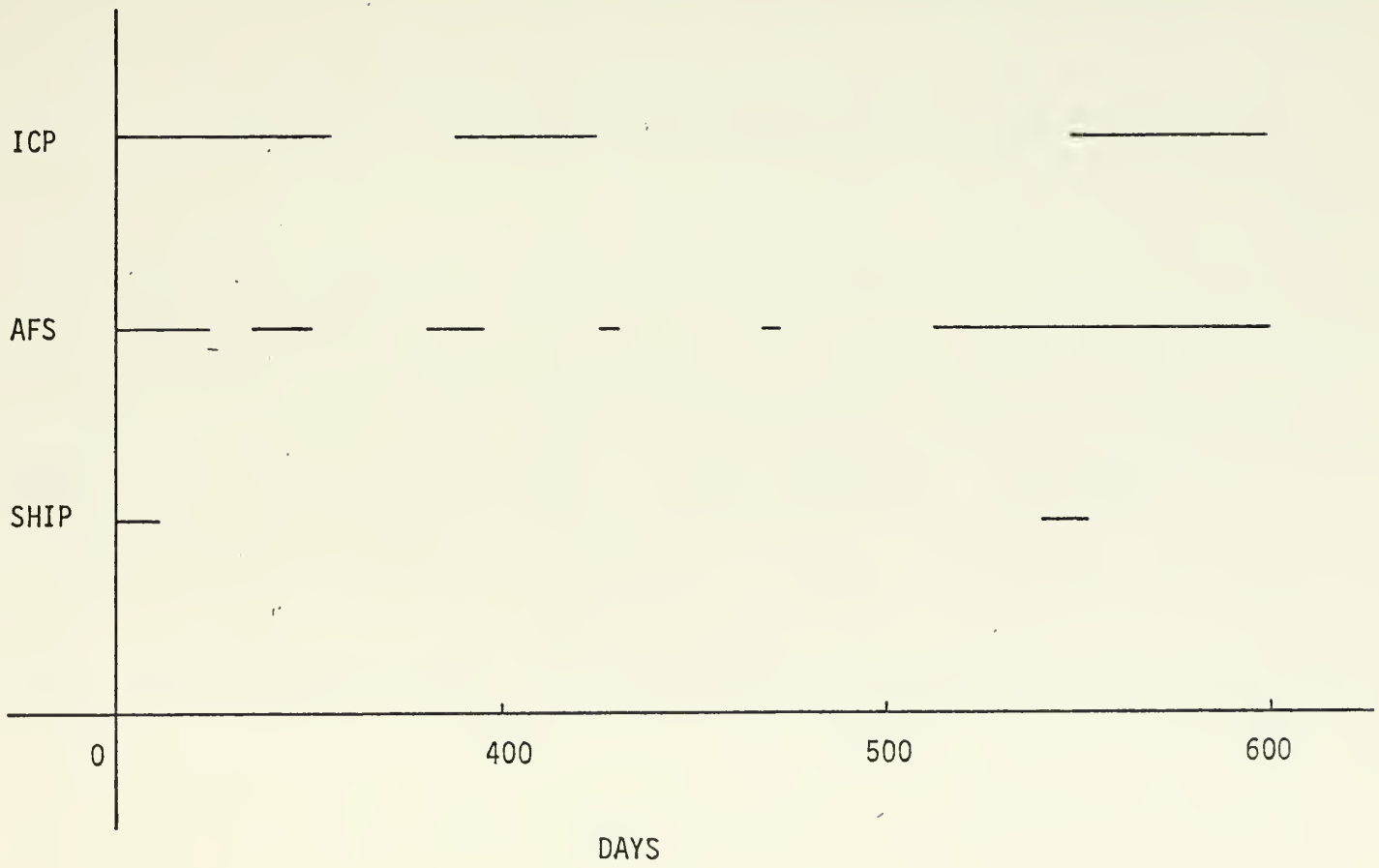

TABLE 4 (Continued). Stock Profile

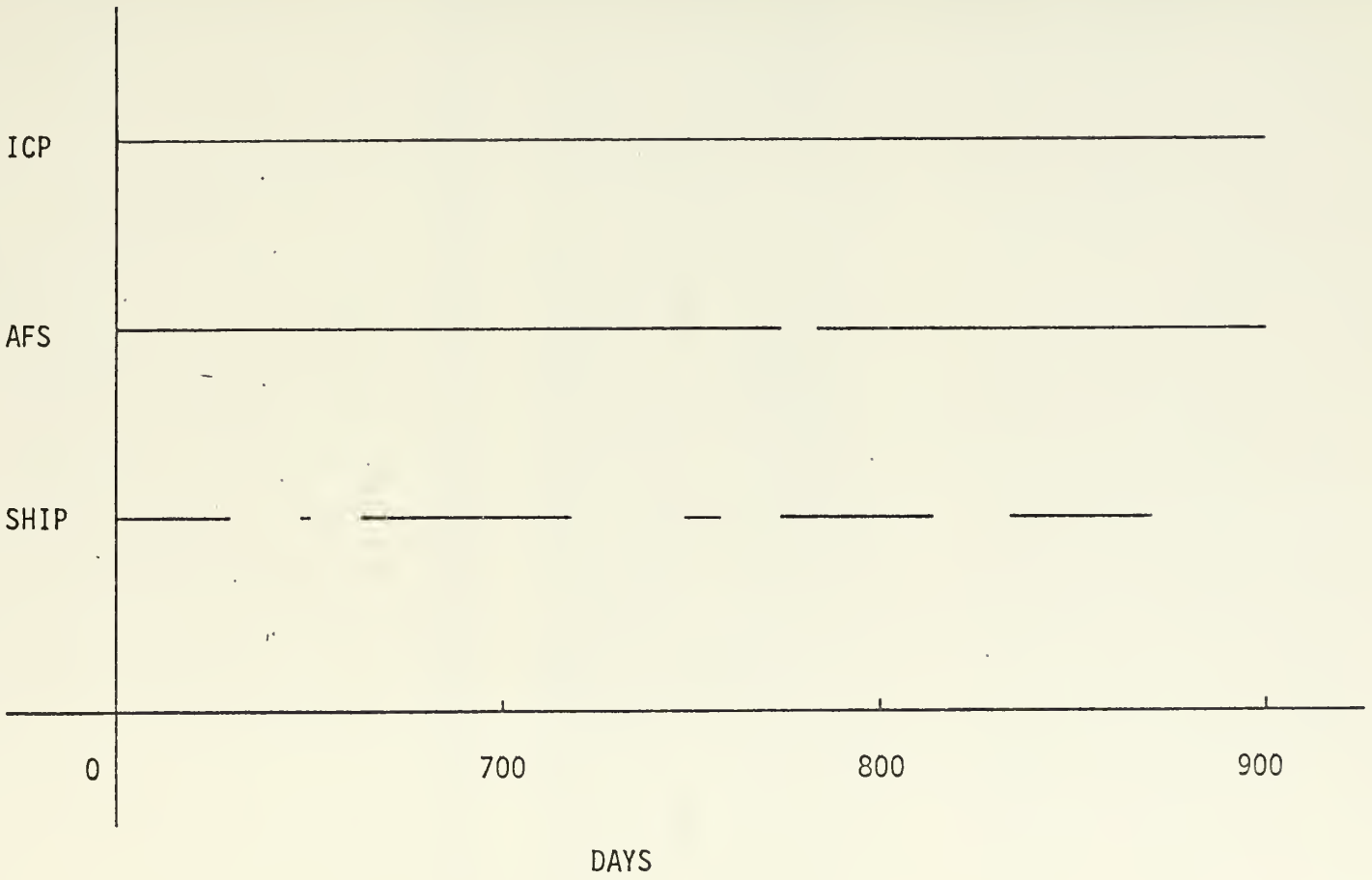

TABLE 4 (Continued). Stock Profile

```
**********************************************************************
*                                                                    *
*  THE PURPOSE OF THIS COMPUTER PROGRAM IS TO SIMULATE A             *
*                                                                    *
*  THREE ECHELON SUPPLY SYSTEM USING A SINGLE ITEM  COSAL.           *
*                                                                    *
*  IT UPDATES BACK ORDERS, IN TRANSIENT, AND ON HAND QUAN-           *
*                                                                    *
*  TITIES ON A DAY-TO-DAY BASIS FOR THREE YEARS AND COM-             *
*                                                                    *
*  PUTES MARGINAL AND CONDITIONAL AVAILABILITIES AT EACH             *
*                                                                    *
*  LEVEL AS WELL AS THE CORRELATIONS OF STOCKOUTS BETWEEN            *
*                                                                    *
*  LEVELS.                                                           *
*                                                                    *
**********************************************************************
```

```
      COMMON/GINO/DEMND(3),IAMNT(3),ICONT(9),ITIME,
     .IQ,IX,IHAN,IBO(4),INTRN(3),IMANU(9),IP,ISENT(3)
     .,IPCON(6),ISHIP(6),IPBO(6),ISBIN(4),IHAND(4),IR,
     .IPTRN(3),IPSENT(3)
      DIMENSION AVERG(3),FAILU(3),A1(3),DMAND(3)
      DIMENSION SHAF(4),SHCP(4),AFCP(4),ESA(4),ESC(4),EAC(4)
      DATA A1/3*0.0/
      DATA CA2/0.0/,CA3/0.0/,CA1/0.0/,DA2/0.0/
      DATA A2/0.0/,A3/0.0/,DMAND/3*0.0/,TOTAL/0.0/
      DATA SH/0.0001/,AF/0.0001/,CP/0.0001/,SHAF/4*0.0/,
     .SHCP/4*0.0/,AFCP/4*0.0/,CHISA/0.0/,CHISC/0.0/,
     .CHIAC/0.0/
      READ (5,1000) AVERG,FAILU,IHAND,IR,IQ,IHAN
 1000 FORMAT(6F6.2,7I2)
      WRITE (6,8081)
 8081 FORMAT('1',' THE PARAMETERS FOR THIS RUN ARE:')
      WRITE(6,9000) AVERG,FAILU,IHAND,IR,IQ,IHAN
 9000 FORMAT(' ',/,6F6.2,7I2,////,' THE DAY-TO-DAY ON-HAND',
     .' STATUS IS:')
      DO 6135 I = 1, 50
      RN=RNM(0)
 6135 CONTINUE
      IP = IHAN
C     DETERMINE TIME TILL FIRST DEMAND & AMOUNT DEMANDED
      DO 100 K = 1,3
      RN=RNM(0)
      DEMND(K)    = -AVERG(K)*ALOG(RN)
      RN=RNM(0)
      IAMNT(K)    = INT(ALOG(RN)/ALOG(FAILU(K))) + 1
  100 CONTINUE
      WRITE(6,3001)
 3001 FORMAT(' ',//,'      SHIP1  SHIP2  SHIP3   AFS',
     .'     ICP    DAY',/)
  109 CONTINUE
C     RUN PROGRAM FOR 45 DAY MLSF TURN AROUND TIME
      DO 106 IMLSF = 1,45
      ITIME = ITIME + 1
      IF(ITIME.GT.1098) GO TO 901
      IPART = 0
      CALL PRIOR(0,1)
      CALL ICP (0,1)
      CALL MLSF (0,1)
C     DETERMINE IF IT IS TIME FOR A DEMAND TO OCCUR
      DO 102 K1 = 1,3
      IF(DEMND(K1).GT.0.0) GO TO 102
      DMAND(K1) = DMAND(K1) + 1.0
      IF(IHAND(K1).LT.IAMNT(K1)) GO TO 121
      A1(K1) = A1(K1) + 1.0
      GO TO 126
  121 CA1 = CA1 + 1.0
  126 IF(IHAND(4).LT.IAMNT(K1)) GO TO 122
      A2 = A2 + 1.0
  122 IF(IHAN.LT.IAMNT(K1)) GO TO 123
      A3 = A3 + 1.0
  123 IF(IHAND(K1).GE.IAMNT(K1)) GO TO 125
      IF(IHAND(4).LT.IAMNT(K1)) GO TO 124
      CA2 = CA2 + 1.0
      GO TO 125
  124 DA2 = DA2 + 1.0
      IF(IHAN.LT.IAMNT(K1)) GO TO 125
      CA3 = CA3 + 1.0
  125 CONTINUE
      IHAND(K1)=IHAND(K1) - IAMNT(K1)
      K = K1
      CALL SHIP (K)
C      DETERMINE TIME TILL NEXT DEMAND & AMOUNT DEMANDED
      RN=RNM(0)
      DEMND(K1) = -AVERG(K1)*ALOG(RN) + 1
      RN=RNM(0)
      IAMNT(K1) = INT(ALOG(RN)/ALOG(FAILU(K1))) + 1
```

```
  102 CONTINUE
      DO 120 K = 1,3
      DEMND(K) = DEMND(K) - 1.0
  120 CONTINUE
      IF(IHAND(1).LE.0) GO TO 181
      SH = SH + 1.0
  181 IF(IHAND(4).LE.0) GO TO 182
        AF = AF + 1.0
  182 IF(IHAN.LE.0) GO TO 183
       CP = CP + 1.0
  183 IF(IHAND(1).LE.0.AND.IHAND(4).LE.0)SHAF(1)=SHAF(1)+1.0
      IF(IHAND(1).LE.0.AND.IHAND(4).GT.0)SHAF(2)=SHAF(2)+1.0
      IF(IHAND(1).GT.0.AND.IHAND(4).LE.0)SHAF(3)=SHAF(3)+1.0
      IF(IHAND(1).GT.0.AND.IHAND(4).GT.0)SHAF(4)=SHAF(4)+1.0
      IF(IHAND(1).LE.0.AND.IHAN.LE.0)SHCP(1)=SHCP(1)+1.0
      IF(IHAND(1).LE.0.AND.IHAN.GT.0)SHCP(2)=SHCP(2)+1.0
      IF(IHAND(1).GT.0.AND.IHAN.LE.0)SHCP(3)=SHCP(3)+1.0
      IF(IHAND(1).GT.0.AND.IHAN.GT.0)SHCP(4)=SHCP(4)+1.0
      IF(IHAND(4).LE.0.AND.IHAN.LE.0)AFCP(1)=AFCP(1)+1.0
      IF(IHAND(4).LE.0.AND.IHAN.GT.0)AFCP(2)=AFCP(2)+1.0
       IF(IHAND(4).GT.0.AND.IHAN.LE.0)AFCP(3)=AFCP(3)+1.0
      IF(IHAND(4).GT.0.AND.IHAN.GT.0)AFCP(4)=AFCP(4)+1.0
  159 IF(ITIME.LT.60) GO TO 152
      IF(ITIME.NE.60) GO TO 161
      WRITE (6,3003)
  161 IF(ITIME.LT.130) GO TO 152
      IF(ITIME.NE.130) GO TO 162
      WRITE (6,3003)
  162 IF(ITIME.LT.200) GO TO 152
      IF(ITIME.NE.200) GO TO 163
      WRITE (6,3003)
  163 IF(ITIME.LT.270) GO TO 152
      IF(ITIME.NE.270) GO TO 164
      WRITE(6,3003)
  164 IF(ITIME.LT.340) GO TO 152
      IF(ITIME.NE.340) GO TO 165
      WRITE(6,3003)
  165 IF(ITIME.LT.410) GO TO 152
      IF(ITIME.NE.410) GO TO 166
      WRITE(6,3003)
  166 IF(ITIME.LT.480) GO TO 152
      IF(ITIME.NE.480) GO TO 167
      WRITE(6,3003)
  167 IF(ITIME.LT.550) GO TO 152
      IF(ITIME.NE.550) GO TO 168
      WRITE(6,3003)
  168 IF(ITIME.LT.620) GO TO 152
      IF(ITIME.NE.620) GO TO 169
      WRITE(6,3003)
  169 IF(ITIME.LT.690) GO TO 152
      IF(ITIME.NE.690) GO TO 170
      WRITE(6,3003)
  170 IF(ITIME.LT.760) GO TO 152
      IF(ITIME.NE.760) GO TO 171
      WRITE(6,3003)
  171 IF(ITIME.LT.830) GO TO 152
      IF(ITIME.NE.830) GO TO 172
      WRITE(6,3003)
  172 IF(ITIME.LT.900) GO TO 152
      IF(ITIME.NE.900) GO TO 173
      WRITE(6,3003)
  173 IF(ITIME.LT.970) GO TO 152
      IF(ITIME.NE.970) GO TO 174
      WRITE(6,3003)
  174 IF(ITIME.LT.1040) GO TO 152
      IF(ITIME.NE.1040) GO TO 152
      WRITE (6,3003)
  152 WRITE(6,3000) IHAND,IHAN,ITIME
 3000 FORMAT(' ',6(3X,I4))
 3003 FORMAT('1','     SHIP1  SHIP2  SHIP3   AFS',
     .'    ICP   DAY',/)
  106 CONTINUE
```

```
C       PICK UP ROUTINE RESUPPLIES FROM ICP
        DO 151 I=1,4
        IHAND(I) = IHAND(I) + ISBIN(I)
        ISBIN(I) = 0
  151 CONTINUE
        GO TO 109
  901 CONTINUE
        DO 131 I = 1,3
        A1(I) = A1(I)/DMAND(I)
        TOTAL = TOTAL + DMAND(I)
  131 CONTINUE
        A2 = A2/TOTAL
        A3 = A3/TOTAL
        CA3 = CA3/DA2
        CA2 = CA2/CA1
        CA1 = 1.0 - CA1/TOTAL
        ESA(1) = (1098.0-SH)*(1098.0-AF)/1098.0
        ESA(2) = (1098.0-SH)*AF/1098.0
        ESA(3) = SH*(1098.0-AF)/1098.0
        ESA(4) = SH*AF/1098.0
        ESC(1) = (1098.0-SH)*(1098.0-CP)/1098.0
        ESC(2) = (1098.0-SH)*CP/1098.0
         ESC(3) = SH*(1098.0-CP)/1098.0
        ESC(4) = SH*CP/1098.0
         EAC(1) = (1098.0-AF)*(1098.0-CP)/1098.0
        EAC(2) = (1098.0-AF)*CP/1098.0
          EAC(3) = AF*(1098.0-CP)/1098.0
         EAC(4) = AF*CP/1098.0
        DO 184 L = 1,4
        CHISA=CHISA+((SHAF(L)-ESA(L))**2)/ESA(L)
         CHISC=CHISC+((SHCP(L)-ESC(L))**2)/ESC(L)
         CHIAC=CHIAC+((AFCP(L)-EAC(L))**2)/EAC(L)
  184 CONTINUE
        CORSA = (SHAF(4) + SHAF(1))/1098.0
        CORSC = (SHCP(4) + SHCP(1))/1098.0
        CORAC = (AFCP(4) + AFCP(1))/1098.0
        WRITE(6,6663)
 6663 FORMAT(' ',/,' THE AVAILABILITIES ARE:',/,'   S1',
     .'      S2      S3      AFS      ICP      CA1      CA2      CA3')
        WRITE(6,3002) A1,A2,A3,CA1,CA2,CA3
 3002 FORMAT(8(1X,F6.4),/)
        WRITE(6,6665)
 6665 FORMAT(' ',20X,' THE CORRELATIONS ARE:',/,20X,
     .'   CORSA    CORSC    CORAC')
        WRITE(6,3004) CORSA,CORSC,CORAC
        WRITE(6,6664)
 6664 FORMAT(' ',20X,' THE CHI SQUARED STATISTICS ARE:',/,
     .20X,'  CHISA   CHISC   CHIAC')
        WRITE(6,3004) CHISA,CHISC,CHIAC
 3004 FORMAT(' ',20X,3(1X,F7.4))
        STOP
        END
```

```
      SUBROUTINE SHIP(K)
C
C     --INVENTORY POSITION OF THE SHIPS,Q=1 POLICY--
C
      COMMON/GINO/DEMND(3),IAMNT(3),ICONT(9),ITIME,
     .IQ,IX,IHAN,IBO(4),INTRN(3),IMANU(9),IP,ISENT(3)
     .,IPCON(6),ISHIP(6),IPBO(6),ISBIN(4),IHAND(4),IR,
     .IPTRN(3),IPSENT(3)
      IF(IHAND(K).GE.0)GO TO 205
      ICHCK = IHAND(K) + IAMNT(K)
      IF(ICHCK.LE.0)GO TO 206
      IAMNT(K) = ICHCK
      IPRIO = -IHAND(K)
      CALL PRIOR(IPRIO,K)
      GO TO 205
  206 IPRIO = IAMNT(K)
      CALL PRIOR(IPRIO,K)
      GO TO 202
  205 IF(IHAND(4).EQ.0)GO TO 204
      IPART = IHAND(4) - IAMNT(K)
      IF(IPART.LT.0)GO TO 201
      IPART = IAMNT(K)
      CALL MLSF(IPART,K)
      GO TO 202
  201 CONTINUE
      IPART = -IPART
      CALL ICP(IPART,K)
      IPART = IHAND(4)
      CALL MLSF(IPART,K)
      GO TO 202
  204 CONTINUE
      IPART = IAMNT(K)
      CALL ICP(IPART,K)
  202 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MLSF(IPART,K)
C
C     --INVENTORY POSITION OF THE MLSF,Q=U POLICY--
C
      COMMON/GINO/DEMND(3),IAMNT(3),ICONT(9),ITIME,
     .IQ,IX,IHAN,IBO(4),INTRN(3),IMANU(9),IP,ISENT(3)
     .,IPCON(6),ISHIP(6),IPBO(6),ISBIN(4),IHAND(4),IR,
     .IPTRN(3),IPSENT(3)
      IF(IPART.EQ.0)GO TO 325
C     IP IS GREATER THAN ORDER SO FILL IT
      IHAND(4) = IHAND(4) - IPART
C     CHECK IF A PART IS INTRANSIT, ADD THIS PART TO IT
      IF(INTRN(K).GT.0)GO TO 350
C     SET THE RANDOM DAYS INTRANSIT COUNTER
      RN=RNM(0)
      ISENT(K) = ITIME + INT(RN*30.0)
C     PUT THE PART INTRANSIT
      INTRN(K) = IPART
      GO TO 320
C     PUT THE ADDITIONAL PART INTRANSIT
  350 INTRN(K) = INTRN(K) + IPART
C     FORWARD ALL REQUISITIONS TO ICP
      KT = K
  320 CALL ICP(IPART,4)
      K = KT
      GO TO  340
C     CHECK TO SEE IF INTRANSIT PARTS HAVE ARRIVED
  325 DO 330 I=1,3
      IF(INTRN(I).EQ.0)GO TO 330
      IF(ISENT(I).GT.ITIME)GO TO 330
      IHAND(I) = IHAND(I) + INTRN(I)
      INTRN(I) = 0
      ISENT(I) = 0
  330 CONTINUE
  340 RETURN
      END
```

```
      SUBROUTINE ICP(IPART,K)
C
C     --INVENTORY POSITION OF THE ICP,(R,Q) POLICY--
C
      COMMON/GINO/DEMND(3),IAMNT(3),ICONT(9),ITIME,
     .IQ,IX,IHAN,IBO(4),INTRN(3),IMANU(9),IP,ISENT(3)
     .,IPCON(6),ISHIP(6),IPBO(6),ISBIN(4),IHAND(4),IR,
     .IPTRN(3),IPSENT(3)
      IF(IPART.EQ.0)GO TO 435
      IF(IPART.GT.IHAN)GO TO 420
C     IP IS GREATER THAN ORDER SO FILL IT
      IHAN = IHAN - IPART
      IP = IP - IPART
      ISBIN(K) = ISBIN(K) + IPART
      GO TO 470
C     IF IP WAS'T LARGE ENOUGH TO FILL ORDER
  420 IF(IHAN.GT.0)GO TO 430
      IHAN = IHAN - IPART
      IP = IP - IPART
      IBO(K) = IBO(K) + IPART
      GO TO 470
C     NOW IF IP CAN FILL CNLY PART OF THE ORDER
  430 ISBIN(K) = ISBIN(K) + IHAN
      IBO(K) = IBO(K) + IPART - IHAN
      IHAN = IHAN - IPART
      IP = IP - IPART
C     CHECK TO SEE IF IT IS TIME TO REORDER
  435 IF(IP.GT.IR) GO TO 444
C     CAN REORDER, BUT CHECK TO SEE IF WE ALREADY HAVE
      DO 440 J=1,9
      IF(IMANU(J).GT.0)GO TO 440
C     OK, REORDER
      IMANU(J) = IQ
      IP = IP + IMANU(J)
C     SET 6 MONTH COUNTER FOR ARRIVAL FROM MANUFACTURER
      ICONT(J) = ITIME + 180
      GO TO 444
  440 CONTINUE
C     HAS THE MANUFACTURED ITEMS ARRIVED
  444 CONTINUE
      DO 460 N=1,9
      IF(IMANU(N).EQ.0)GO TO 460
      IF(ICONT(N).GT.ITIME)GO TO 460
C     YES
      DO 450 I=1,4
C     CAN THE BO BE FILLED
      IF(IMANU(N).LE.IBO(5-I))GO TO 445
C     YES
      IMANU(N) = IMANU(N) - IBO(5-I)
      ISBIN(5-I) = ISBIN(5-I) + IBO(5-I)
      IBO(5-I) = 0
      GO TO 450
C     BO CAN BE PARTIALLY FILLED
  445 IBO(5-I) = IBO(5-I) - IMANU(N)
      ISBIN(5-I) = ISBIN(5-I) + IMANU(N)
      IMANU(N) = 0
  450 CONTINUE
      IMANU(N) = 0
  460 CONTINUE
  470 RETURN
      END
```

```
      SUBROUTINE PRIOR (IPRIO,K)
C
C     --THIS IS THE SUBROUTINE FOR PRIORITY REQUISITIONS-
C
      COMMON/GINO/DEMND(3),IAMNT(3),ICONT(9),ITIME,
     .IQ,IX,IHAN,IBO(4),INTRN(3),IMANU(9),IP,ISENT(3)
     .,IPCON(6),ISHIP(6),IPBO(6),ISBIN(4),IHAND(4),IR,
     .IPTRN(3),IPSENT(3)
      IF(IPRIO.EQ.0) GO TO 330
      IF(IHAND(4).LE.0) GO TO 710
      IPCHK = IHAND(4) - IPRIO
      IF(IPCHK.LT.0) GO TO 720
      IF(IPSENT(K).GT.0) GO TO 740
      IF(ISENT(K).EQ.0) GO TO 730
      IPTIME = ISENT(K) - ITIME
      IPSENT(K) =  MINO(8,IPTIME) + ITIME
      GO TO 740
  730 IPSENT(K) = 8 + ITIME
  740 IHAND(4) = IHAND(4) - IPRIO
      IPTRN(K) = IPTRN(K) + IPRIO
      IPART = IPRIO
      KT = K
      CALL ICP (IPART,4)
      K = KT
      RETURN
  720 IF(IPSENT(K).GT.0) GO TO 760
      IF(ISENT(K).EQ.0)GO TO 750
      IPTIME = ISENT(K) - ITIME
      IPSENT(K) =  MINO(8,IPTIME) + ITIME
      GO TO 760
  750 IPSENT(K) = 8 + ITIME
  760 IPTRN(K) = IPTRN(K) + IHAND(4)
      IHAND(4) = 0
      IPART = IHAND(4)
      KT = K
      CALL ICP (IPART,4)
      K = KT
      IPRIO = -IPCHK
  710 DO 770 J = 1,3
      IF(INTRN(J).EQ.0) GO TO 770
      IPCHK = INTRN(J) -IPRIO
      IF(IPCHK.LT.0) GO TO 780
      IF(IPSENT(K).GT.0) GO TO 790
      IF(ISENT(K).EQ.0) GO TO 711
      IPTIME = ISENT(K) - ITIME
      IPSENT(K) =  MINO(8,IPTIME) + ITIME
      GO TO 790
  711 IPSENT(K) = 8 + ITIME
  790 INTRN(J) = INTRN(J) - IPRIO
      IPTRN(K) = IPTRN(K) + IPRIO
      IPART = IPRIO
      CALL ICP (IPART,J)
      RETURN
  780 IF(IPSENT(K).GT.0) GO TO 721
      IF(ISENT(K).EQ.0) GO  TO 731
      IPTIME = ISENT(K) - ITIME
      IPSENT(K) =  MINO(8,IPTIME) + ITIME
      GO TO 731
  731 IPSENT(K) = 8 + ITIME
  721 IPTRN(K) = IPTRN(K) + INTRN(J)
      INTRN(J) = 0
      IPART = INTRN(J)
      CALL ICP (IPART,J)
      IPRIO = -IPCHK
      IF(IPRIO.EQ.0) RETURN
  770 CONTINUE
C     THIS IS THE ICP PORTION OF THE PRIORITY SUBROUTINE
      IF(IPRIO.GT.IHAN)GO TO 310
```

```
C       THE ORDER CAN BE FILLED, PUT THE PART IN SHIPMENT
        IHAN = IHAN - IPRIO
        IP = IP - IPRIO
        IF(ISHIP(K).GT.0)GO TO 305
        ISHIP(K) = IPRIO
C       SHIPMENT TAKES 21 DAYS
        IPCON(K) = ITIME + 21
        GO TO 800
  305   ISHIP(K+3) = IPRIO
        IPCON(K+3) = ITIME + 21
        GO TO 800
  310   IF(IHAN.GT.0)GO TO 320
C       NO PARTS ON HAND SO BACKORDER ALL OF THE PARTS
        IHAN = IHAN - IPRIO
        IP = IP - IPRIO
        IPBO(K) = IPBO(K) + IPRIO
        GO TO 800
C       PART OF THE ORDER SHIPPED AND PART BACKORDERED
  320   IF(ISHIP(K).GT.0)GO TO 325
        ISHIP(K) = IHAN
C       SHIPMENT TAKES 21 DAYS
        IPCON(K) = ITIME + 21
        GO TO 326
  325   ISHIP(K+3) = IHAN
        IPCON(K+3) = ITIME + 21
  326   IPBO(K) = IPBO(K) + IPRIO - IHAN
        IHAN = IHAN - IPRIO
        IP = IP - IPRIO
        GO TO 800
C       HAVE PARTS ARRIVED FROM MANUFACTURER TODAY
  330   DO 340 N=1,9
        IF(IMANU(N).EQ.0)GO TO 340
        IF(ICONT(N).GT.ITIME)GO TO 340
        IHAN = IHAN + IQ
C       SOME PARTS HAVE ARRIVED, SO FILL PRIORITY BO'S
        DO 360 J=1,3
        IF(IMANU(N).LE.IPBO(J))GO TO 350
        IMANU(N) = IMANU(N) - IPBO(J)
        ISHIP(J) = ISHIP(J) + IPBO(J)
        IPCON(J) = ITIME + 21
        IPBO(J) = 0
        GO TO 360
  350   IF(IMANU(N).EQ.0)GO TO 340
C       PARTIALLY FILL PRIORITY BACKORDERS
        IPBO(J) = IPBO(J) - IMANU(N)
        ISHIP(J) = ISHIP(J) + IMANU(N)
        IPCON(J) = ITIME + 21
        IMANU(N) = 0
  360   CONTINUE
  340   CONTINUE
C       HAVE ANY PARTS ARRIVED AT THE SHIPS
  751   DO 741 J = 1,3
        IF(IPTRN(J).EQ.0) GO TO 741
        IF(IPSENT(J).GT.ITIME) GO TO 741
        IHAND(J) = IHAND(J) + IPTRN(J)
        IPTRN(J) = 0
        IPSENT(J) = 0
  741   CONTINUE
        DO 370 I=1,6
        IF(ISHIP(I).EQ.0)GO TO 370
C       THE SHIPMANT HAS ARRIVED, ADD IT TO SHIP'S ON HAND
        IF(IPCON(I).GT.ITIME)GO TO 370
        IF(I.GT.3)GO TO 375
        IHAND(I) = IHAND(I) + ISHIP(I)
        GO TO 376
  375   IHAND(I-3) = IHAND(I-3) + ISHIP(I)
  376   ISHIP(I) = 0
  370   CONTINUE
  800   CONTINUE
        RETURN
        END
```

```
      BLOCK DATA
      COMMON/GINO/DEMND(3),IAMNT(3),ICONT(9),ITIME,
     .IO,IX,IHAN,IBO(4),INTRN(3),IMANU(9),IP,ISENT(3)
     .,IPCON(6),ISHIP(6),IPBO(6),ISBIN(4),IHAND(4),IR,
     .IPTRN(3),IPSENT(3)
      DATA IMANU/9*0/,ICONT/9*0/,ITIME/0/,IPBO/3*0/
      DATA ISBIN/4*0/,IBO/4*0/,INTRN/3*0/,ISENT/3*0/
      DATA IPSENT/3*0/,IPTRN/3*0/,IPCON/6*0/,ISHIP/6*0/
      END
```

SAMPLE OUTPUT FOR THE SINGLE ITEM MODEL

THE PARAMETERS FOR THIS RUN ARE:
90.00 90.00 90.00 0.05 0.05 0.05 1 1 1 2 7 4 9

THE DAY-TO-DAY ON-HAND STATUS IS:

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
1	1	1	2	9	1
1	1	1	2	9	2
1	1	1	2	9	3
1	1	1	2	9	4
1	1	1	2	9	5
1	1	1	2	9	6
1	1	1	2	9	7
1	1	1	2	9	8
1	1	1	2	9	9
1	1	1	2	9	10
1	1	1	2	9	11
1	1	1	2	9	12
1	1	1	2	9	13
1	1	1	2	9	14
1	1	1	2	9	15
1	1	1	2	9	16
1	1	1	2	9	17
1	1	1	2	9	18
1	1	1	2	9	19
1	1	1	2	9	20
1	1	1	2	9	21
1	1	1	2	9	22
1	1	1	2	9	23
1	1	1	2	9	24
1	1	1	2	9	25
1	1	1	2	9	26
1	1	1	2	9	27
1	1	1	2	9	28
1	1	1	2	9	29
1	1	1	2	9	30
1	1	1	2	9	31
1	1	1	2	9	32
1	1	1	2	9	33
1	1	1	2	9	34
1	1	1	2	9	35
1	1	1	2	9	36
1	1	1	2	9	37
1	1	1	2	9	38
1	1	1	2	9	39
1	1	1	2	9	40
1	1	1	2	9	41
1	1	1	2	9	42
1	1	1	2	9	43
1	1	1	2	9	44
1	1	1	2	9	45
1	1	1	2	9	46
1	1	1	2	9	47
1	1	1	2	9	48
1	1	1	2	9	49
1	1	1	2	9	50
1	1	1	2	9	51
1	1	1	2	9	52
1	1	1	2	9	53
1	1	1	2	9	54
1	1	1	2	9	55
1	1	0	1	8	56
1	1	0	1	8	57
1	1	0	1	8	58
1	1	0	1	8	59

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
1	1	0	1	8	60
1	1	0	1	8	61
1	1	0	1	8	62
1	1	0	1	8	63
1	1	0	1	8	64
1	1	-1	0	7	65
1	1	-1	0	7	66
1	1	-1	0	7	67
1	1	-1	0	7	68
1	1	-1	0	7	69
1	1	-1	0	7	70
1	1	-1	0	7	71
1	1	-1	0	7	72
1	1	0	0	7	73
1	1	0	0	7	74
1	1	0	0	7	75
1	1	0	0	7	76
1	1	0	0	7	77
1	1	0	0	7	78
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1	1	1	0	7	81
1	1	1	0	7	82
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1	1	0	1	6	101
1	1	0	1	6	102
1	1	0	1	6	103
1	1	0	1	6	104
1	1	1	1	6	105
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1	1	1	1	6	109
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1	1	1	1	6	111
1	1	1	1	6	112
1	1	1	1	6	113
1	1	1	1	6	114
1	1	1	1	6	115
1	1	1	1	6	116
1	1	1	1	6	117
1	1	1	1	6	118
1	1	1	1	6	119
1	1	1	1	6	120
1	1	1	1	6	121
1	1	1	1	6	122
1	1	1	1	6	123
1	1	1	1	6	124
1	1	1	1	6	125
1	1	1	1	6	126
1	1	1	1	6	127
1	1	1	1	6	128
1	1	1	1	6	129

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
1	1	1	1	6	130
1	1	1	1	6	131
1	1	1	1	6	132
1	1	1	1	6	133
1	1	1	1	6	134
1	1	1	1	6	135
1	1	1	2	6	136
1	1	1	2	6	137
1	1	1	2	6	138
1	1	1	2	6	139
1	1	1	2	6	140
1	1	1	2	6	141
1	1	1	2	6	142
1	1	1	2	6	143
1	1	1	2	6	144
1	1	1	2	6	145
1	1	1	2	6	146
1	1	1	2	6	147
1	1	1	2	6	148
1	1	1	2	6	149
1	1	1	2	6	150
1	1	1	2	6	151
1	1	1	2	6	152
1	1	1	2	6	153
1	1	1	2	6	154
1	1	1	2	6	155
1	1	1	2	6	156
1	1	1	2	6	157
1	1	1	2	6	158
1	1	1	2	6	159
1	1	1	2	6	160
1	1	1	2	6	161
1	1	1	2	6	162
1	1	1	2	6	163
1	1	1	2	6	164
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1	1	1	2	6	166
1	1	1	2	6	167
1	1	0	1	5	168
1	1	0	1	5	169
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1	0	0	0	4	177
1	0	0	0	4	178
1	0	0	0	4	179
1	0	0	0	4	180
1	0	0	2	4	181
1	0	1	2	4	182
1	0	1	2	4	183
1	1	1	2	4	184
1	1	1	2	4	185
1	1	1	2	4	186
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1	1	1	2	4	194
1	0	1	1	3	195
1	0	1	1	3	196
1	0	1	1	3	197
1	0	1	1	3	198
1	0	1	1	3	199

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
1	0	1	1	3	200
1	0	1	1	3	201
1	0	1	1	3	202
0	0	1	0	2	203
0	0	0	0	1	204
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0	1	0	0	1	209
0	1	0	0	1	210
0	1	0	0	1	211
0	1	0	0	1	212
0	1	0	0	1	213
0	1	0	0	1	214
0	1	0	0	1	215
0	1	0	0	1	216
0	1	0	0	1	217
0	1	0	0	1	218
0	1	0	0	1	219
0	1	0	0	1	220
0	1	0	0	1	221
0	1	0	0	1	222
0	1	0	0	1	223
0	1	0	0	1	224
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1	1	1	2	1	227
1	1	1	2	1	228
1	1	1	2	1	229
1	1	1	2	1	230
1	1	1	2	1	231
1	1	1	2	1	232
1	1	1	2	1	233
1	1	1	2	1	234
1	1	1	2	1	235
1	1	1	2	1	236
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1	1	1	2	1	245
1	1	1	2	5	246
1	1	1	2	5	247
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1	1	1	2	5	252
1	1	1	2	5	253
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1	1	1	2	5	263
1	1	1	2	5	264
1	1	1	2	5	265
1	1	1	2	5	266
1	1	1	2	5	267
1	1	1	2	5	268
1	1	1	2	5	269

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
1	1	1	2	5	270
1	1	1	2	5	271
1	1	1	2	5	272
1	1	1	2	5	273
1	1	1	2	5	274
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1	1	1	2	5	279
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1	1	1	2	5	282
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1	1	1	2	5	284
1	1	1	2	5	285
1	1	1	2	5	286
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1	1	1	2	5	288
-1	1	1	0	3	289
-1	1	1	0	3	290
-1	1	1	0	3	291
-1	1	1	0	3	292
-1	1	1	0	3	293
-1	1	1	0	3	294
-1	1	1	0	3	295
-1	1	1	0	3	296
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0	1	1	0	3	299
0	1	1	0	3	300
0	1	1	0	3	301
0	1	1	0	3	302
0	1	1	0	3	303
0	1	1	0	3	304
0	1	1	0	3	305
0	1	1	0	3	306
0	1	1	0	3	307
0	1	1	0	3	308
0	1	1	0	3	309
0	1	1	0	3	310
0	1	1	0	3	311
0	1	1	0	3	312
0	1	1	0	3	313
0	1	1	0	3	314
0	1	1	0	3	315
0	1	1	2	3	316
1	1	1	2	3	317
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1	1	0	0	1	329
1	1	0	0	1	330
1	1	1	0	1	331
1	1	1	0	1	332
1	1	1	0	1	333
1	1	1	0	1	334
1	-1	1	0	-1	335
1	-1	1	0	-1	336
1	-1	1	0	-1	337
1	-1	1	0	-1	338
1	-1	1	0	-1	339

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
1	-1	1	0	-1	340
1	-1	1	0	-1	341
1	-2	1	0	-2	342
1	-2	1	0	-2	343
1	-2	1	0	-2	344
1	-2	1	0	-2	345
1	-2	1	0	-2	346
1	-2	1	0	-2	347
1	-2	1	0	-2	348
1	-2	1	0	-2	349
1	-2	1	0	-2	350
1	-2	1	0	-2	351
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1	-1	1	0	-2	356
1	-1	1	0	-2	357
1	-1	1	0	-2	358
1	-1	1	0	-2	359
1	-1	1	0	-2	360
1	-1	1	2	-2	361
1	-1	1	2	-2	362
1	-1	1	2	-2	363
1	-1	1	2	-2	364
1	-1	1	2	-2	365
1	-1	1	2	-2	366
1	-1	1	2	-2	367
1	-1	1	2	-2	368
1	-1	1	2	-2	369
1	-1	1	2	-2	370
1	-1	1	2	-2	371
1	-1	1	2	-2	372
1	-1	1	2	-2	373
1	-1	1	2	-2	374
1	-1	1	2	-2	375
1	-1	1	2	2	376
1	-2	1	1	1	377
1	-2	1	1	1	378
1	-2	1	1	1	379
1	-2	1	1	1	380
1	-2	1	1	1	381
1	-2	1	1	1	382
1	-2	1	1	1	383
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0	0	1	0	0	404
0	0	1	0	0	405
0	1	1	2	0	406
0	1	1	2	0	407
0	1	1	2	0	408
0	1	1	2	0	409

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
0	1	1	2	0	410
0	1	1	2	0	411
0	1	1	2	0	412
0	1	1	2	0	413
1	1	1	2	0	414
1	0	1	1	-1	415
1	0	1	1	-1	416
1	0	1	1	-1	417
1	0	1	1	-1	418
1	0	1	1	-1	419
1	0	1	1	-1	420
1	0	1	1	-1	421
1	0	1	1	-1	422
1	0	1	1	-1	423
1	0	1	1	-1	424
1	0	1	1	-1	425
1	0	1	1	-1	426
1	0	1	1	-1	427
1	0	1	1	-1	428
1	0	1	1	-1	429
1	0	1	1	-1	430
1	0	1	1	-1	431
1	0	1	1	-1	432
1	0	1	1	-1	433
1	0	1	1	-1	434
1	0	1	1	-1	435
1	0	1	1	-1	436
1	0	1	1	-1	437
1	0	1	1	-1	438
1	0	1	1	-1	439
1	0	1	1	-1	440
1	0	1	1	-1	441
1	1	1	1	-1	442
1	1	1	1	-1	443
1	1	1	1	-1	444
1	1	1	1	-1	445
1	1	1	1	-1	446
1	1	1	1	-1	447
1	1	1	1	-1	448
1	1	1	1	-1	449
1	1	1	1	-1	450
1	1	1	1	-1	451
1	1	1	1	-1	452
1	1	1	1	-1	453
1	1	1	1	-1	454
1	1	1	1	-1	455
1	1	1	1	-1	456
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1	0	1	0	-2	458
1	0	1	0	-2	459
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1	0	1	0	-2	468
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1	0	1	0	2	470
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1	0	1	0	2	472
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1	0	1	0	2	474
1	1	1	0	2	475
1	1	1	0	2	476
1	1	1	0	2	477
1	1	1	0	2	478
1	1	1	0	2	479

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
1	1	1	0	2	480
1	1	1	0	2	481
1	1	1	0	2	482
1	1	1	0	2	483
1	1	1	0	2	484
1	1	1	0	2	485
1	1	1	0	2	486
1	1	1	0	2	487
1	1	1	0	2	488
1	1	1	0	2	489
1	1	1	0	2	490
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0	0	1	0	4	531
0	-1	1	0	3	532
0	-1	1	0	3	533
0	-1	1	0	3	534
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SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
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0	1	0	0	1	623
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SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
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-1	1	-1	2	-2	722
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0	1	0	2	-2	745
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0	1	0	2	-2	747
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0	0	0	1	-3	749
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0	0	0	1	-3	755
0	0	0	1	-3	756
0	0	0	1	-3	757
0	0	0	1	1	758
0	0	0	1	1	759

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
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0	1	0	1	1	762
0	1	-1	0	0	763
0	1	-1	0	0	764
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SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
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1	1	1	2	4	832
1	1	1	2	4	833
1	1	1	2	4	834
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SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
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-1	1	1	0	2	968
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SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
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0	1	1	1	3	1039

SHIP1	SHIP2	SHIP3	AFS	ICP	DAY
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1	1	0	0	1	1080
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1	1	1	2	1	1097
0	1	1	1	0	1098

THE AVAILABILITIES ARE:

S1	S2	S3	AFS	ICP	CA1	CA2	CA3
0.6154	0.7647	0.8125	0.7174	0.7391	0.7391	0.4167	0.4286

THE CORRELATIONS ARE:

CORSA	CORSC	CORAC
0.7468	0.6740	0.6375

THE CHI SQUARED STATISTICS ARE:

CHISA	CHISC	CHIAC
197.1279	62.6127	35.4347

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**********************************************************
*                                                        *
*  THE PURPOSE OF THIS COMPUTER PROGRAM IS TO SIMULATE A *
*                                                        *
*  THREE ECHELON SUPPLY SYSTEM USING A MULTI-ITEM COSAL . *
*                                                        *
*  IT UPDATES BACK ORDER, IN TRANSIENT, AND ON HAND QUAN- *
*                                                        *
*  TITIES ON A DAY-TO-DAY BASIS FOR THREE YEARS AND COM- *
*                                                        *
*  PUTES MARGINAL AND CONDITIONAL AVAILABILITIES AT EACH *
*                                                        *
*  LEVEL.                                                *
*                                                        *
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      COMMON/GINO/DEMND(50),ICONT(9,50),ITIME,ISBIN(2,50)
     .,IHAND(50,3),IR(50),IQ(50),IBO(2,50),INTRN(50),
     .IMANU(9,50),IP(50),IPTRN(50),ISENT(50),IPSENT(50),
     .IPCON(2,50),ISHIP(2,50),IPBO(50),AVERG(50)
C
      DIMENSION A1(50),DMAND(50),A2(50),A3(50),CA1(50),
     ,CA2(50),CA3(50),DA2(50)
      DATA A1/50*0.0/,A2/50*0.0/,A3/50*0.0/,CA1/50*.0001/
      DATA CA2/50*0.0/,CA3/50*0.0/,DA2/50*.0001/
      DATA DMAND/50*.0001/,TOTAL/0.0/
      DO 6135 I = 1,50
      RN = RNM(0)
      IP(I) = IHAND(I,3)
 6135 CONTINUE
      DO 100 K = 1,50
      RN = RNM(0)
      DEMND(K) = -AVERG(K)*ALOG(RN)
  100 CONTINUE
  109 CONTINUE
      DO 106 IMLSF = 1,45
      ITIME = ITIME + 1
      DO 153 K1 = 1,50
      IF(ISENT(K1).EQ.0) GO TO 154
      ISENT(K1) = ISENT(K1) - 1
  154 IF(IPSENT(K1).EQ.0) GO TO 153
      IPSENT(K1) = IPSENT(K1) - 1
  153 CONTINUE
      K = 51
      CALL PRIOR(51)
      CALL ICP (1,51)
      CALL MLSF(51)
      IF(ITIME.GT.1120) GO TO 901
      DO 102 K1 = 1,50
      IF(DEMND(K1).GT.0.0) GO TO 102
      DMAND(K1) = DMAND(K1) + 1.0
      IF(IHAND(K1,1).LT.1) GO TO 121
      A1(K1) = A1(K1) + 1.0
      GO TO 126
  121 CA1(K1) = CA1(K1) + 1.0
  126 IF(IHAND(K1,2).LT.1) GO TO 122
      A2(K1) = A2(K1) + 1.0
  122 IF(IHAND(K1,3).LT.1) GO TO 123
      A3(K1) = A3(K1) + 1.0
  123 IF(IHAND(K1,1).GE.1) GO TO 125
      IF(IHAND(K1,2).LT.1) GO TO 124
      CA2(K1) = CA2(K1) + 1.0
      GO TO 125
  124 DA2(K1) = DA2(K1) + 1.0
      IF(IHAND(K1,3).LT.1) GO TO 125
      CA3(K1) = CA3(K1) + 1.0
  125 CONTINUE
      IHAND(K1,1) = IHAND(K1,1) - 1
      K = K1
      CALL SHIP (K)
      RN = RNM(0)
      DEMND(K1) = -AVERG(K1)*ALOG(RN) + 1.0
  102 CONTINUE
      DO 120 L = 1,50
      DEMND(L) = DEMND(L) - 1.0
  120 CONTINUE
      DO 103 L = 1,3
      IF(IHAND(L,1).LT.0) GO TO 107
  103 CONTINUE
     GO TO 106
  107 AVAIL = AVAIL + 1.0
      AVAIL = 1.0-(AVAIL/1098.0)
  106 CONTINUE
      DO 151 J = 1,2
      DO 152 L = 1,50
      IHAND(L,J) = IHAND(L,J) + ISBIN(J,L)
      ISBIN(J,L) = 0
```

```
  152 CONTINUE
  151 CONTINUE
      GO TO 109
  901 CONTINUE
      DO 131 L = 1,50
      A1(L) = A1(L)/DMAND(L)
      TOTAL = TOTAL + DMAND(L)
      A2(L) = A2(L)/DMAND(L)
      A3(L) = A3(L)/DMAND(L)
      CA3(L) = CA3(L)/CA2(L)
      CA2(L) = CA2(L)/CA1(L)
      CA1(L) = 1.0 - CA1(L)/DMAND(L)
  131 CONTINUE
      WRITE(6,3101)
 3101 FORMAT('1',////,15X,'MARGINAL AVAILABILITIES AT THE',
     .' SHIP ARE:'/)
      WRITE(6,3003)A1
      WRITE(6,3102)
 3102 FORMAT(//15X,' CONDITIONAL AVAILABILITIES AT THE',
     .' SHIP ARE:'/)
      WRITE(6,3003)CA1
      WRITE(6,3103)
 3103 FORMAT('1',////,15X,'MARGINAL AVAILABILITIES AT THE',
     .' AFS ARE:'/)
      WRITE(6,3003)A2
      WRITE(6,3104)
 3104 FORMAT(//15X,'CONDITIONAL AVAILABILITIES AT THE',
     .' AFS ARE:'/)
      WRITE(6,3003)CA2
      WRITE(6,3105)
 3105 FORMAT('1',////,15X,'MARGINAL AVAILABILITIES AT THE',
     .' ICP ARE:'/)
      WRITE(6,3003)A3
      WRITE(6,3107)
 3107 FORMAT(//15X,'CONDITIONAL AVAILABILITIES AT THE',
     .' ICP ARE:'/)
      WRITE(6,3003)CA3
 3003 FORMAT(10(15X,5(3X,F6.4)//))
      WRITE(6,5252) AVAIL
 5252 FORMAT(' ',///,15X,'THE SYSTEM OPERATIONAL AVAILABI',
     .'LITY IS',2X,F6.4)
      STOP
      END
```

```
      SUBROUTINE SHIP(K)
C
CC    --SUPPLY POSITION OF THE SHIP,50 PARTS,Q=1 POLICY--
C
      COMMON/GINO/DEMND(50),ICONT(9,50),ITIME,ISBIN(2,50)
     .,IHAND(50,3),IR(50),IQ(50),IBO(2,50),INTRN(50),
     .IMANU(9,50),IP(50),IPTRN(50),ISENT(50),IPSENT(50),
     .IPCON(2,50),ISHIP(2,50),IPBO(50),AVERG(50)
      IF(IHAND(K,1).GE.0) GO TO 205
      ICHCK = IHAND(K,1) + 1
      IF(ICHCK.LE.0) GO TO 206
      GO TO 205
  206 CONTINUE
      CALL PRIOR(K)
      GO TO 202
  205 IF(IHAND(K,2).EQ.0) GO TO 204
      CALL MLSF (K)
      GO TO 202
  204 CONTINUE
      CALL ICP (1,K)
  202 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MLSF(K)
C
C     ----INVENTORY POSITION OF THE MLSF, Q=IPOLICY----
C
      COMMON/GINO/DEMND(50),ICONT(9,50),ITIME,ISBIN(2,50)
     .,IHAND(50,3),IR(50),IQ(50),IBO(2,50),INTRN(50),
     .IMANU(9,50),IP(50),IPTRN(50),ISENT(50),IPSENT(50),
     .IPCON(2,50),ISHIP(2,50),IPBO(50),AVERG(50)
C
      IF(K.EQ.51)GO TO 325
C     IP IS GREATER THAN ORDER SO FILL IT
      IHAND(K,2)  = IHAND(K,2) - 1
C     CHECK IF A PART IS INTRANSIT,IF SO,ADD THIS PART
      IF(INTRN(K).GT.0) GO TO 350
C     SET RANDOM DAYS INTRANSIT COUNTER,PUT PART INTRANSIT
      IITIME = ITIME + 15
      ISENT(K)  = 29 - MOD(IITIME,30)
      INTRN(K)  = 1
      GO TO 320
C     PUT THE ADDITIONAL PART INTRANSIT
  350 INTRN(K) = INTRN(K) + 1
C     FORWARD ALL REQUISITIONS TO ICP
  320 CALL ICP(2,K)
      GO TO 340
C     CHECK TO SEE IF INTRANSIT PARTS HAVE ARRIVED
  325 DO 330 J = 1,50
      IF(INTRN(J).EQ.0)GO TO 330
      IF(ISENT(J).GT.0)GO TO 330
      IHAND(J,1)  = IHAND(J,1) + INTRN(J)
      INTRN(J) = 0
      ISENT(J) = 0
  330 CONTINUE
  340 RETURN
      END
```

```
      SUBROUTINE ICP(IW,K)
C
C     --INVENTORY POSITION OF THE ICP, (R,Q) POLICY--
C
      COMMON/GINO/DEMND(50),ICONT(9,50),ITIME,ISBIN(2,50)
     .,IHAND(50,3),IR(50),IQ(50),IBO(2,50),INTRN(50),
     .IMANU(9,50),IP(50),IPTRN(50),ISENT(50),IPSENT(50),
     .IPCON(2,50),ISHIP(2,50),IPBO(50),AVERG(50)
      IF(K.EQ.51)GO TO 435
      IF(IHAND(K,3).LE.0) GO TO 420
C     IP IS GREATER THAN ORDER SO FILL IT
      IHAND(K,3) = IHAND(K,3) - 1
      IP(K) = IP(K) - 1
      ISBIN(IW,K) = ISBIN(IW,K) + 1
      GO TO 470
C     IF IP WAS'T LARGE ENOUGH TO FILL ORDER
  420 IHAND(K,3) = IHAND(K,3) - 1
      IP(K) = IP(K) - 1
      IBO(IW,K) = IBO(IW,K) + 1
      GO TO 470
C     CHECK TO SEE IF IT IS TIME TO REORDER
  435 DO 444 I=1,50
      IF(IP(I).GT.IR(I)) GO TO 444
C     CAN REORDER,CHECK TO SEE IF WE ALREADY HAVE
      DO 440 J=1,9
      IF(IMANU(J,I).GT.0)GO TO 440
C     OK. REORDER AND SET THE 6 MONTHS COUNTER
      IMANU(J,I) = IMANU(J,I) + IQ(I)
      IP(I) = IP(I) + IMANU(J,I)
      ICONT(J,I) = ITIME + 180
      GO TO 441
  440 CONTINUE
  441 CONTINUE
  444 CONTINUE
C     HAVE THE MANUFACTURED ITEMS ARRIVED
      DO 465 I=1,50
      DO 460 N=1,9
      IF(IMANU(N,I).EQ.0)GO TO 460
      IF(ICONT(N,I).GT.ITIME)GO TO 460
      DO 450 J=1,2
C     FILL THE BACKORDERS
      IF(IMANU(N,I).LE.IBO(3-J,I))GO TO 445
      IMANU(N,I) = IMANU(N,I) - IBO(3-J,I)
      ISBIN(3-J,I) = ISBIN(3-J,I) + IBO(3-J,I)
      IBO(3-J,I) = 0
      GO TO 450
C     BO CAN BE PARTIALLY FILLED
  445 IBO(3-J,I) = IBO(3-J,I) - IMANU(N,I)
      ISBIN(3-J,I) = ISBIN(3-J,I) + IMANU(N,I)
      IMANU(N,I) = 0
  450 CONTINUE
      IMANU(N,I) = 0
  460 CONTINUE
  465 CONTINUE
  470 RETURN
      END
C
```

```
      SUBROUTINE PRIOR (K)
C
C     --THIS IS THE PRIORITY PORTION OF THE PROGRAM---
C
      COMMON/GINO/DEMND(50),ICONT(9,50),ITIME,ISBIN(2,50)
     .,IHAND(50,3),IR(50),IQ(50),IBO(2,50),INTRN(50),
     .IMANU(9,50),IP(50),IPTRN(50),ISENT(50),IPSENT(50),
     .IPCON(2,50),ISHIP(2,50),IPBO(50),AVERG(50)
      IF(K.EQ.51) GO TO 330
      IF(IHAND(K,2).EQ.0) GO TO 710
      IF(IPSENT(K).GT.0) GO TO 740
      IITIME = ITIME + 15
      IPTIME = 29 - MOD(IITIME,30)
      IF(ISENT(K).EQ.0) GO TO 730
      IPSENT(K)   = MINO(8,IPTIME)
      GO TO 740
  730 IPSENT(K) = 8
  740 IHAND(K,2) = IHAND(K,2) - 1
      IPTRN(K) = IPTRN(K) + 1
      CALL ICP (2,K)
      RETURN
  710 DO 770 J = 1,50
      IF(INTRN(J).EQ.0) GO TO 770
      IF(IPSENT(K).GT.0) GO TO 790
      IF(ISENT(K).EQ.0) GO TO 711
      IITIME = ITIME + 15
      IPTIME = 29 - MOD(IITIME,30)
      IPSENT(K) = MINO(8,IPTIME)
      GO TO 790
  711 IPSENT(K) =  8
  790 INTRN(J) = INTRN(J) - 1
      IPTRN(K) = IPTRN(K) + 1
      CALL ICP (1,J)
      RETURN
  770 CONTINUE
C
C     THIS IS ICP PORTION OF THE PRIORITY SUBROUTINE
      IF(IHAND(K,3).EQ.0)GO TO 310
C     THE ORDER CAN BE FILLED,PUT THE PART IN SHIPMENT
      IHAND(K,3) = IHAND(K,3) -1
      IP(K) = IP(K) - 1
      IF(ISHIP(1,K).GT.0) GO TO 305
      ISHIP(1,K) = 1
C     SHIPMENT TAKES 21 DAYS
      IPCON(1,K) = ITIME + 21
      GO TO 800
  305 ISHIP(2,K) = 1
      IPCON(2,K) = ITIME + 21
      GO TO 800
C     NO PARTS ON HAND,BACKORDER ALL OF THE PARTS
  310 IHAND(K,3) = IHAND(K,3) -1
      IP(K) = IP(K) - 1
      IPBO(K) = IPBO(K) + 1
      GO TO 800
C     ANY PARTS ARRIVE FROM THE MANFACTURER TODAY
  330 DO 345 J =1,50
      DO 340 N=1,9
      IF(IMANU(N,J).EQ.0)GO TO 340
      IF(ICONT(N,J).GT.ITIME)GO TO 340
      IHAND(J,3) = IHAND(J,3) + IQ(J)
C     PARTS ARRIVED FROM MANUFACTURER,FILL PRIORITY BO
      IF(IMANU(N,J).LE.IPBO(J))GO TO 350
      IMANU(N,J) = IMANU(N,J) - IPBO(J)
      ISHIP(1,J) = ISHIP(1,J) + IPBO(J)
      IPCON(1,J) = ITIME + 21
      IPBO(J) = 0
      GO TO 360
  350 IF(IMANU(N,J).EQ.0)GO TO 340
```

```
C       PARTIALLY FILL PRIORITY BACKORDERS
        IPBO(J) = IPBO(J) - IMANU(N,J)
        ISHIP(1,J) = ISHIP(1,J) + IMANU(N,J)
        IPCON(1,J) = ITIME + 21
        IMANU(N,J) = 0
  360 CONTINUE
  340 CONTINUE
  345 CONTINUE
C       HAVE ANY PARTS ARRIVED AT THE SHIPS
  751 DO 741 J=1,50
        IF(IPTRN(J).EQ.0)GO TO 741
        IF(IPSENT(J).GT.0)GO TO 741
        IHAND(J,1) = IHAND(J,1) + IPTRN(J)
        IPTRN(J) = 0
        IPSENT(J) = 0
  741 CONTINUE
        DO 380 J=1,50
        DO 370 I=1,2
        IF(ISHIP(I,J).EQ.0)GO TO 370
        IF(IPCON(I,J).GT.ITIME)GO TO 370
C       THE SHIPMENT HAS ARRIVED SO ADD IT TO THE SHIP' ON HAN
        IHAND(J,1) = IHAND(J,1) + ISHIP(I,J)
        ISHIP(I,J) = 0
  370 CONTINUE
  380 CONTINUE
  800 CONTINUE
        RETURN
        END
```

```
      BLOCK DATA
      COMMON/GINO/DEMND(50),ICONT(9,50),ITIME,ISBIN(2,50)
     .,IHAND(50,3),IR(50),IQ(50),IBO(2,50),INTRN(50),
     .IMANU(9,50),IP(50),IPTRN(50),ISENT(50),IPSENT(50),
     .IPCON(2,50),ISHIP(2,50),IPBO(50),AVERG(50)
      DATA IMANU/450*0/,ICONT/450*0/,ITIME/0/
      DATA ISBIN/100*0/,IBO/100*0/,INTRN/50*0/
      DATA IPSENT/50*0/,IPTRN/50*0/,IPCON/100*0/
      DATA ISENT/50*0/,ISHIP/100*0/,IPBO/50*0/
      DATA AVERG/5*300.0,5*120.0,5*60.0,5*30.0,5*20.0,
     .5*15.0,5*10.0,5*8.0,5*6.0,5*3.0/
      DATA IR/5*0,5*1,5*2,5*4,5*7,5*10,5*15,5*20,5*25,5*60/
      DATA IQ/15*1,5*3,5*4,5*6,5*9,5*12,5*15,5*30/
      DATA IHAND/5*0,10*1,5*2,5*3,4*4,5*6,5*7,5*8,5*18,
     .5*0,10*2,5*3,5*5,5*6,5*9,5*11,5*12,5*27,
     .0,1,1,2,3,0,1,2,2,2,1,2,3,3,3,2,4,5,6,7,4,7,8,9,11,
     .5,10,11,13,16,8,15,16,20,24,10,20,21,26,32,13,25,
     .26,33,40,30,60,61,75,90/
      END
```

SAMPLE OUTPUT FOR THE MULTI-ITEM MODEL

MARGINAL AVAILABILITIES AT THE SHIP ARE:

0.0	0.0	0.0	0.0	0.0
0.7500	0.7000	0.8750	0.6667	0.8889
0.4500	0.9000	0.4286	0.4000	0.3810
0.6897	0.4857	0.7000	0.6970	0.4706
0.6481	0.7619	0.7609	0.8958	0.7091
0.9464	0.9483	1.0000	1.0000	1.0000
1.0000	0.9897	0.9709	1.0000	1.0000
1.0000	1.0000	1.0000	0.9915	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	0.0

CONDITIONAL AVAILABILITIES AT THE SHIP ARE:

0.0	0.0	0.0	0.0	0.0
0.7500	0.7000	0.8750	0.6667	0.8889
0.4500	0.9000	0.4286	0.4000	0.3810
0.6897	0.4857	0.7000	0.6970	0.4706
0.6481	0.7619	0.7609	0.8958	0.7091
0.9464	0.9483	1.0000	1.0000	1.0000
1.0000	0.9897	0.9709	1.0000	1.0000
1.0000	1.0000	1.0000	0.9915	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	0.0

MARGINAL AVAILABILITIES AT THE AFS ARE:

0.0	0.0	0.0	0.0	0.8333
1.0000	1.0000	1.0000	0.8889	1.0000
0.7000	1.0000	0.8571	0.9000	0.8571
0.8621	0.6571	0.9333	0.8485	0.9412
0.8333	0.9048	0.9783	0.9375	0.9091
0.9821	0.9483	1.0000	1.0000	1.0000
0.9727	1.0000	0.9417	1.0000	1.0000
1.0000	0.9915	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	1.0000	1.0000	1.0000	0.0

CONDITIONAL AVAILABILITIES AT THE AFS ARE:

0.0	0.0	0.0	0.0	0.8333
0.9999	1.0000	0.9999	0.6666	0.9999
0.5454	0.9999	0.7500	0.8333	0.7692
0.5555	0.3333	0.7778	0.5000	0.8889
0.5263	0.6000	0.9091	0.8000	0.7500
1.0000	0.3333	0.0	0.0	0.0
0.0	0.9999	1.0000	0.0	0.0
0.0	0.0	0.0	0.9999	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0

MARGINAL AVAILABILITIES AT THE ICP ARE:

0.6667	1.0000	1.0000	1.0000	0.5000
0.5000	0.3000	0.3750	0.3333	0.4444
0.3000	0.8000	0.4286	0.1500	0.1429
0.2414	0.4000	0.3333	0.4242	0.2059
0.1852	0.5000	0.5652	0.4792	0.4182
0.6071	0.7414	0.7460	0.8448	0.9000
0.5455	0.8351	0.7087	0.8586	0.8842
0.9237	0.8559	0.7754	0.9153	0.8053
0.9444	0.9281	1.0000	0.9732	0.8690
1.0000	1.0000	1.0000	1.0000	0.8168

CONDITIONAL AVAILABILITIES AT THE ICP ARE:

0.6667	1.0000	1.0000	1.0000	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.3333	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.8168

THE SYSTEM OPERATIONAL AVAILABILITY IS 0.9217

****
****
****

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ABSTRACT

The Ships Supply Support Study developed a fleet supply support simulator in which supply support dollar outlays may be related to fleet capability. A critical assumption made in the development of the simulator states that the availability of a item at a given echelon is independent of its availability at other echelons. A computer model of a single item multi-echelon supply support system is constructed. A day by day history of the status of each entity in the system is obtained along with an in and out of stock profile for the item by calendar time at each echelon. Marginal availabilities and conditional availabilities are compared, and other measures of the degree of dependence of echelon availabilities are presented. Finally, the computer model is extended to consider a multi-item supply system and similar tests are made.

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Operational Availability						
Simulation						
Stock Profile						
Alternating Renewal Process						

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An investigation of the independence between supply echelons for the ships Supply Support Study.